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A brief overview of discard estimation methods where observer coverage is unavailable

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Introduction

Recent estimates of commercial discards for most New England commercial groundfish species are determined using the combined ratio method (Wigley et al. 2007). This method provides unbiased estimates of discards, however it requires direct observations of discards by at-sea observers. Prior to the implementation of the Northeast Fisheries Observer Program (NEFOP) in 1989, domestic at-sea observer coverage was limited (occasional trips were observed by various fishery biologist staff). To estimate discards prior to 1989 (or where observer coverage is insufficient) other methods must be employed. In this paper, we summarize two alternate methods used to estimate discards for New England groundfish species utilizing Northeast Fisheries Science Center (NEFSC) research vessel survey relative biomass indices: survey-scaling method and survey-filtering method.

Method 1: Survey-scaling method

The 'survey-scaling method' may be used to hindcast discarded fish when observer data are available for a portion of the time series but not for the entire period. Using observer data, an average combined d/k ratio over a range of years is derived where *d* is the discard pounds of a given species and *k* is the kept pounds of all species. The total landed pounds of all species is used to expand the discard rate to estimate total discard weight. The estimated discard weight is scaled by the ratio of the relative biomass index to the average of relative biomass index based over a range of years (Equation 1). This method is based on the assumption that discard weight of given species is a function of the relative population biomass.

(1) $$\hat{D}_{j,t,h} = \bar{r}_{c,j,base,h} \bullet K_{t,h} \bullet \left(\frac{I_{j,t}}{\bar{I}_{j,base}} \right)$$

where

$\hat{D}$ is the estimated discarded pounds of species *j* for fleet *h* in year *t*;

$\bar{r}_c$ is the average combined d/k_{all} ratio of species *j* over a range of years, *base*, for fleet *h;*

K is the total landings (mt) survey biomass index of species *j* in year *t*;

$\bar{I}$ is the average NEFSC survey biomass index of the species *j* over a range of years, *base.*

This method assumes that a multi-year average of the fleet-specific combined ratio estimator (Wigley et al. 2007) is appropriate to apply back in time where observer coverage is unavailable. This assumption holds if there have been no major changes to the fishery (e.g., closed areas, minimum mesh sizes, trip limits). Most New England groundfish fisheries have undergone significant changes in recent history primarily in response to regulations, however for some fisheries these changes are not sufficient to violate the basic assumption.

1a. Survey-scaling method with minimum size restrictions: an example using Gulf of Maine haddock

The Gulf of Maine haddock fishery has experienced several regulatory changes since 1977 including changes in the minimum mesh size, minimum retention size, trip limits, and rolling and permanent area closures. With the exception of the period from 1994 to 1997 when possession limits ranging from 500 to 1,000 lb/day were in place, Gulf of Maine haddock are primarily discarded because of minimum size limits (Table 1). Trip limits remained in place after 1997 but they were less restrictive. Prior to 1994 the discard reason was either not specified or not recorded by the NEFOP, but it is assumed that the primary reason for discards in the period before 1994 are the same as the most current period (2003 to 2006), i.e., below minimum size. It is unknown whether groundfish quotas in place in the late 1970's to early 1980's resulted in significant discarding of legal sized fish. The combined ratio, r_c, from the recent period (2003 to 2006) are comparable to those prior to 1994 for most fleets (Table 2; limited or no coverage was available for three of the six estimated fleets prior to 1994). It was assumed that an average of the current fleet discard ratios (2003 to 2006) could be applied back in time to estimate historical discards by considering changes to the minimum size limits and relative changes in abundance of the undersized and exploitable fraction of the population as determined by NEFSC autumn bottom trawl survey biomass.

The undersized and exploitable fraction of the population is assumed to represent that portion of the population that is vulnerable to capture by fleet, h, but below the minimum size limit allowed. The survey biomass index of the undersized and exploitable fraction was calculated by summing the biomass index at lengths for all length classes between the minimum discarded size by gear type (from Northeast Fisheries Observer Program data) and the minimum size limits on landed fish for each year (converted to fork length using FL = 0.944TL + 0.58, Livingstone 1956). In years where no size limits were in place (prior to 1977) it was assumed that market demand drove the minimum retained size. The length corresponding to the 5^{th} percentile observed in the commercial length samples of Gulf of Maine haddock was assumed to represent the market-determined annual minimum landed length. Commercial length samples were unavailable prior to 1969. For these years an average of the 1969 to 1976 minimum landed length was used. If survey indices are particularly noisy, it may be desirable to smooth the annual survey biomass indices using a moving average or similar approach.

Comparison of discards estimated by the survey-scaling method relative to the combined ratio agree relatively well except for those years where restrictive trips limits are not in place (1994 – 1997) and/or abnormally strong year classes are present (appearance of 1998 year class from 1999 to 2001, Figure 1).

Method 1b: Survey-scale method for species with no minimum size restrictions: an example using ocean pout

For species with no minimum sizes restrictions and little or no market demand (e.g., ocean pout) a variation of the survey-scaling method can be used. This method is analogous to Method 1a, with the exception that the survey biomass index is not restricted to the undersized and exploitable fraction

For ocean pout, the discards estimated by the survey-scaling method are generally higher than discards estimated using the combined ratio (d/k_{all}) method as well as discards estimated using a discard to days absent ratio as used in GARM 2005 (Wigley and Col 2005; Figure 2). While the survey biomass indices could be trimmed to exclude fish that would not be caught with commercial mesh sizes, observer data indicates that fish as small as 8 cm are caught in commercial otter trawl gear. Examination of the survey length frequency data indicate that generally less than 3% of stratified mean number per tow are less than 20 cm in length; thus the relative biomass associated with this fraction does not appreciably impact the discard estimates.

Method 1c: Exception for stocks with low survey detectability: the example of windowpane flounder

For stocks with low survey detectability such as windowpane flounder, in may be inappropriate to scale discard estimates by survey biomass. Noisy surveys can lead to highly variable and potentially improbable discard estimates. For these stocks a variation of Eq. 1 can be used where the right hand side (i.e., the scaling factor) is deleted. The discard estimate becomes the landings in time, *t*, for fleet, *h*, ($K_{t,h}$) multiplied by the average combined d/k_{all} ratio, $\bar{r}_c$.

Method 2: Survey-filter method

Method 2a: Survey-filter method with sufficient length data

The 'survey filter method' can be used to hindcast discarded fish when observer data are not available. Specific application of this method to stock assessments can be found in Mayo *et al.* (1992) and O'Brien and Esteves (2001). This method is based on the assumption that landings and discards of fish are a function of both abundance and fishing effort. The landings can be estimated from the abundance of a particular species measured by the NEFSC research survey index of number per tow (N_i) filtered through both a trawl mesh selection ogive (m_i) and a culling or sorting ogive (s_i). Discards are then estimated as ($1\text{-}s_i$).

For a given level of abundance, a unit of fishing effort will produce a unit of catch, including discards. The proportionality constant (q) between effort and catch must be estimated and may be a function of depth, area, and time of year. Thus, the overall level of catch (landings and discard) in the fishery becomes a function of abundance as well as the quantity and distribution of fishing effort.

Starting with the catch equation

(2.1) $$C = F/(F+M) \bullet [1\text{-}exp^{-(F+M)}] \bullet N$$

catch is a function of population size (N) and some measure of exploitation, which can be viewed as either fishing mortality (F) or fishing effort (f). Since

(2.2) $$F = q \bullet f,$$

the catch equation can be expressed generally in terms of effort,

(2.3) $$C = (q \bullet f) \bullet N.$$

Simulating the kept and discarded portions of the catch based on bottom trawl survey abundance indices.

When the bottom trawl survey abundance index corresponds to the season and area of the fishery, the catch per unit of effort at length will be proportional to the survey abundance index at length adjusted for mesh selection by commercial trawls as follows.

If:

(2.4) $C_i/f = q \bullet (N_i \bullet m_i)$, then

(2.5) $C_i = (q \bullet f) \bullet (N_i \bullet m_i)$ as above.

If :

(2.6) $K_i = C_i \bullet s_i$, and

(2.7) $D_i = C_i \bullet (1\text{-}s_i)$, then

(2.8) $D_i = (q \bullet f) \bullet (N_i \bullet m_i) \bullet (1\text{-}s_i)$,

where:

C_i is the catch retained by a given commercial mesh at length i,
N_i is the abundance of fish in the survey at length i,
m_i is the proportion of the available population retained by a given mesh at length i,
s_i is the proportion of the retained catch kept at length i,
K_i is the kept portion of the catch at length i, and
D_i is the discarded portion of the catch at length i.

Estimating the proportionality constant (q) between abundance as measured by the survey and landings/effort in the fishery

As described for catch above, landings (L) at length are proportional to effort (f) and to the abundance of fish retained at length ($N_i \bullet m_i$) by the constant q. Since,

(2.9) $L_i = (q \bullet f) \bullet (N_i \bullet m_i)$, and

(2.10) $L_i/f = q \bullet (N_i \bullet m_i)$, then

(2.11) $q = (L_i/f) / (N_i \bullet m_i)$.

Therefore, q is the proportionality between fish abundance and the landings at length per unit of effort. It is therefore, the catchability constant between CPUE of a commercial trawl (C/f) and the survey abundance index adjusted for mesh selection ($N \bullet m$).

Similarly,

(2.12) $D_i /f = q \bullet [N_i \bullet m_i \bullet (1\text{-}s_i)]$,

since the amount discarded per unit of effort in the fishery will be proportional to the abundance of fish in the discard length range. Estimates of q can be obtained from this relationship by regression of D/f on $N \bullet m \bullet (1\text{-}s)$ using the observer data (or the landings data) and bottom trawl survey data. The estimates of q obtained from this analysis can then be used to estimate discards in years when observer data are not available (prior to 1989). Discards at length can be estimated as

(2.13) $D_i = f \bullet q \bullet [N_i \bullet m_i \bullet (1\text{-}s_i)]$.

Method 2b: Survey-filtering method with sparse length data

A variation of the method described above uses a semi-annual ratio estimator of survey filtered 'kept' index to semi-annual numbers landed to expand the estimated 'discard' survey index to obtain numbers of fish discarded at length. This variation differs from Method 2a above which employs an expansion factor derived from a linear regression from the ratios of kept to landed at length. This variation is useful for less abundant species which may have missing values at length. A spreadsheet illustrating Method 2b is presented in Table 3 for 1993 using the spring survey and commercial landings from quarters 1 and 2. Semi-annual numbers of discard fish at length were apportioned to age using the corresponding season NEFSC age-length key. In general, the discard estimates from the survey-filtered method were higher than estimates derived using the d/k ratio method. Further details on witch flounder discards are described in Wigley et al. (2003).

Given the distribution of juvenile witch flounder in the western Gulf of Maine and the recent implementation of year-around area closures and seasonal rolling area closures in the western Gulf of Maine, it would not be appropriate to apply the survey filter method to estimate discards, i.e. the NEFSC survey samples areas which are not available to the fishing fleets.

Conclusions

The 'survey scaling' and 'survey-filter' hindcast methods are objective approaches for approximating the potential magnitude of historical discard data. Such information is important for the proper estimation of scale in stock assessment models and for temporally consistent measures of population trend. In the absence of such information the estimates of fishing mortality and biomass will be biased. The magnitude of the bias can be accommodated through changes in survey q's or natural mortality rates in models which can estimate both quantities. Natural mortality and discards both represent inferred quantities of unobserved deaths. The former is generally assumed to be a constant. Hindcast estimates of discards are temporally varying in response to biological attributes of the catch or survey and magnitude of landings. As such they may be more informative than simple assumptions of constant instantaneous rates.

At present, neither method addresses the imprecision of extrapolating beyond the historical range of the observer data. Thus these estimates should be considered as informative but not definitive. The appropriate method for a given stock must be selected in the context of entire suite of information about a stock. Knowledge of the historical fisheries is particularly relevant to this selection.

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Tables

Table 1. Percent occurrence of discard reasons for Gulf of Maine haddock from Northeast Fisheries Observer Program (NEFOP), 1989 to 2006. Percent occurrence is expressed as percentage of total annual discard weight for a specific discard reason to the total discard weight of the species where a discard reason was provided (i.e., not null records were not included in this analysis).

Year	Discard reason by percent of total weight					Total weight of discards with discard reason available (lb)	Count of observed hauls with discard reasons available
	Other / unknown	Quota filled / retention prohibited	Upgraded	Poor quality	Below minimum size		
1989	49.3	0.0	0.0	50.7	0.0	69	6
1990	66.7	0.0	0.0	33.3	0.0	30	2
1991	71.1	0.0	0.0	28.9	0.0	225	7
1992	79.8	0.0	0.0	20.2	0.0	297	8
1993	72.2	13.6	0.0	14.2	0.0	316	8
1994	47.8	42.7	0.0	0.0	9.5	216	23
1995	22.5	46.9	0.0	0.5	30.1	1,794	127
1996	1.0	29.6	13.1	5.6	50.7	1,095	120
1997	4.8	34.5	0.0	50.5	10.2	4,173	56
1998	44.2	0.0	0.0	4.4	51.4	91	15
1999	9.9	0.0	0.0	76.5	13.6	81	17
2000	0.2	0.0	0.0	22.6	77.3	532	42
2001	2.6	0.0	0.0	3.9	93.5	696	72
2002	4.9	0.0	0.0	16.0	79.1	614	85
2003	1.9	0.0	0.0	7.7	90.3	1,544	250
2004	48.6	0.0	0.0	9.0	42.5	2,876	296
2005	24.8	0.6	0.0	13.3	61.3	5,178	558
2006	0.9	0.0	0.0	2.7	96.4	2,854	183
2007	12.2	0.0	0.0	34.5	53.2	3,006	160

Table 2. Number of observed trips and combined ratio of Gulf of Maine haddock discards to the amount of retained amount of all species for the benthic longline, large mesh otter trawl, small mesh otter trawl, paired-midwater otter trawl and midwater otter trawl fleets, 1989 – 2006.

Year	Longline, benthic		Otter trawl, bottom, large mesh (≥ 5.5")		Otter trawl, bottom, small mesh (< 5.5")		Gillnet, sink		Otter trawl, paired-midwater		Otter trawl, midwater	
	d_{had}/K_{all} ratio	number of trips	d_{had}/K_{all} ratio	number of trips	d_{had}/K_{all} ratio	number of trips	d_{had}/K_{all} ratio	number of trips	d_{had}/K_{all} ratio	number of trips	d_{had}/K_{all} ratio	number of trips
1989			0.0003	37	0.0000	23	0.0002	84				
1990			0.0000	26	0.0000	8	0.0001	120				
1991	0.0006	2	0.0001	48	0.0000	29	0.0001	801				
1992	0.0000	9	0.0006	44	0.0000	15	0.0001	896				
1993	0.0000	2	0.0012	17	0.0000	6	0.0002	560				
1994			0.0043	6			0.0005	85				
1995			0.0068	25	0.0002	30	0.0004	69			0.0000	4
1996			0.0049	11	0.0008	40	0.0013	46				
1997			0.0250	5	0.0000	3	0.0000	33				
1998			0.0015	6			0.0002	78				
1999			0.0001	21	0.0001	11	0.0002	73	0.0000	2		
2000			0.0020	79			0.0010	81			0.0000	3
2001			0.0008	113	0.0060	4	0.0008	47				
2002	0.0000	1	0.0007	149	0.0006	35	0.0018	80				
2003	0.0153	14	0.0006	253	0.0005	19	0.0009	295	0.0000	8	0.0000	1
2004	0.0018	8	0.0007	258	0.0017	67	0.0006	775	0.0000	41	0.0002	20
2005	0.0194	58	0.0008	498	0.0004	69	0.0007	651	0.0001	63	0.0001	27
2006	0.0221	36	0.0035	206	0.0004	24	0.0005	128	0.0000	7	0.0000	7
Average	0.0074	16	0.0030	100	0.0007	26	0.0005	272	0.0000	24	0.0000	10

Table 3. Example of the spreadsheet calculations for estimating semi-annual discarded witch flounder in the large-mesh otter trawl fishery. This spreadsheet illustrates 1993, quarters 1 and 2 with the NEFSC spring survey. The bold numbers indicate columns and the mathematical operation performed.

1993 Landings from Q1+Q2 and 1993 spring survey								
	1	**2**	**3=1*2**	**4**	**5=3*4**	**6=3-5**	**7**	**8=6*factor**
		140 mm					100's	units
Length	Survey	Prop.	Survey	Prop	Survey	Survey	Numbers	Numbers
(cm)	No/tow	Retained	Retained	Kept	Kept	Discarded	Landed	Discarded
1	0.000	0.00005	0.0000	0.00	0.0000	0.0000	0	0
3	0.000	0.00008	0.0000	0.00	0.0000	0.0000	0	0
5	0.034	0.00015	0.0000	0.00	0.0000	0.0000	0	34
7	0.064	0.00028	0.0000	0.00	0.0000	0.0000	0	120
9	0.051	0.00051	0.0000	0.00	0.0000	0.0000	0	174
11	0.000	0.00092	0.0000	0.00	0.0000	0.0000	0	0
13	0.000	0.00168	0.0000	0.00	0.0000	0.0000	0	0
15	0.011	0.00305	0.0000	0.00	0.0000	0.0000	0	224
17	0.067	0.00554	0.0004	0.00	0.0000	0.0004	0	2483
19	0.042	0.01005	0.0004	0.00	0.0000	0.0004	0	2823
21	0.028	0.01816	0.0005	0.00	0.0000	0.0005	0	3401
23	0.042	0.03261	0.0014	0.00	0.0000	0.0014	0	9161
25	0.061	0.05787	0.0035	0.00	0.0000	0.0035	0	23612
27	0.165	0.10065	0.0166	0.00	0.0000	0.0166	0	111083
29	0.079	0.16938	0.0134	0.00	0.0000	0.0134	0	89503
31	0.205	0.27091	0.0555	0.01	0.0006	0.0550	0	367759
33	0.165	0.40372	0.0666	0.10	0.0067	0.0600	231	401011
35	0.152	0.55231	0.0840	0.99	0.0831	0.0008	2519	5615
37	0.076	0.69211	0.0526	1.00	0.0526	0.0000	4892	0
39	0.042	0.80377	0.0338	1.00	0.0338	0.0000	3984	0
41	0.050	0.88184	0.0441	1.00	0.0441	0.0000	3143	0
43	0.000	0.93150	0.0000	1.00	0.0000	0.0000	1699	0
45	0.000	0.96121	0.0000	1.00	0.0000	0.0000	1658	0
47	0.000	0.97833	0.0000	1.00	0.0000	0.0000	1293	0
49	0.054	0.98799	0.0534	1.00	0.0534	0.0000	1268	0
51	0.046	0.99337	0.0457	1.00	0.0457	0.0000	1225	0
53	0.000	0.99635	0.0000	1.00	0.0000	0.0000	812	0
55	0.018	0.99799	0.0180	1.00	0.0180	0.0000	486	0
57	0.000	1.0000	0.0000	1.00	0.0000	0.0000	354	0
59	0.000	1.0000	0.0000	1.00	0.0000	0.0000	198	0
61	0.000	1.0000	0.0000	1.00	0.0000	0.0000	72	0
63	0.019	1.0000	0.0190	1.00	0.0190	0.0000	27	0
65	0.000	1.0000	0.0000	1.00	0.0000	0.0000	4	0
67	0.000	1.0000	0.0000	1.00	0.0000	0.0000	0	0
69	0.000	1.0000	0.0000	1.00	0.0000	0.0000	0	0
71	0.000	1.0000	0.0000	1.00	0.0000	0.0000	0	0
TOTAL	1.471		0.5088		0.3568	0.1520	2,386,500	1,017,003
							Factor = 6,688,621	
1: From SURVAN, stratified mean number per tow at length.							(col 7/ col 5)	

2: From LOGEST Program using 140 mm mesh in 1993 from adjusted 130-d mm from Walsh et al. (1992) for

4: knife-edge at 36 cm

7: From Length BIOSTAT

Figures

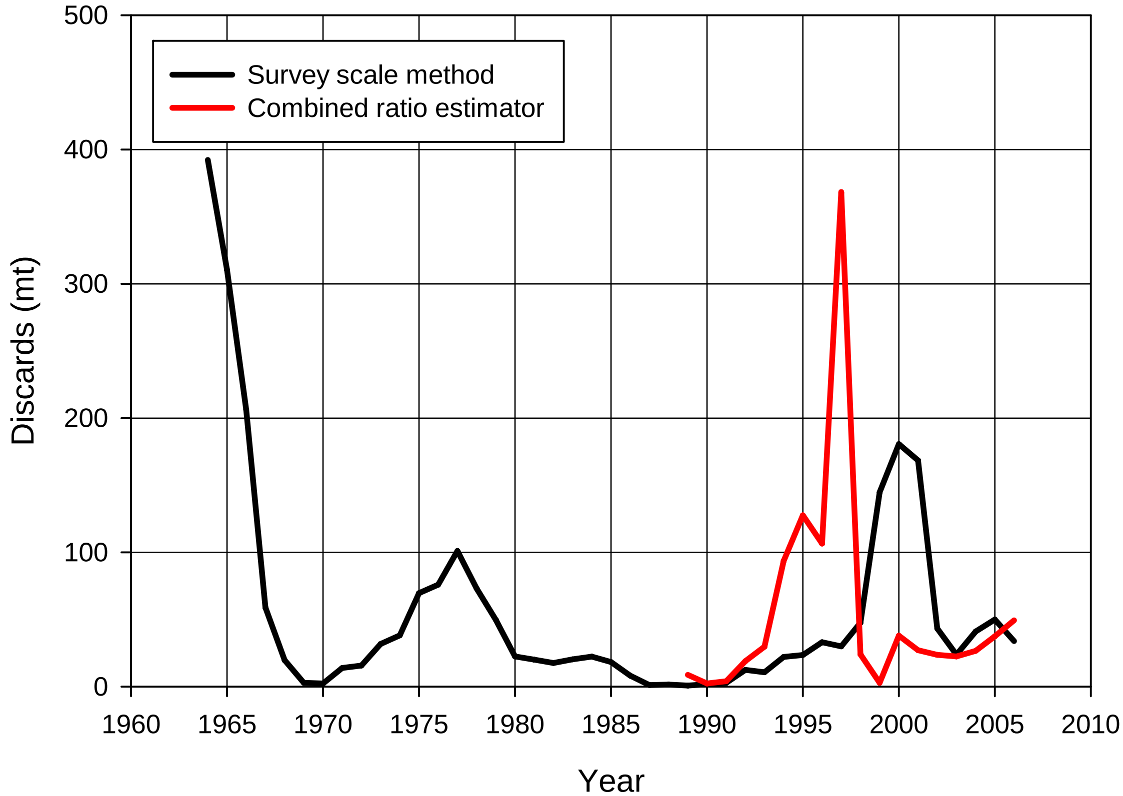

Figure 1. Comparison of Gulf of Maine haddock commercial discards estimated using the survey-scale method to discards estimated using the combined-ratio method.

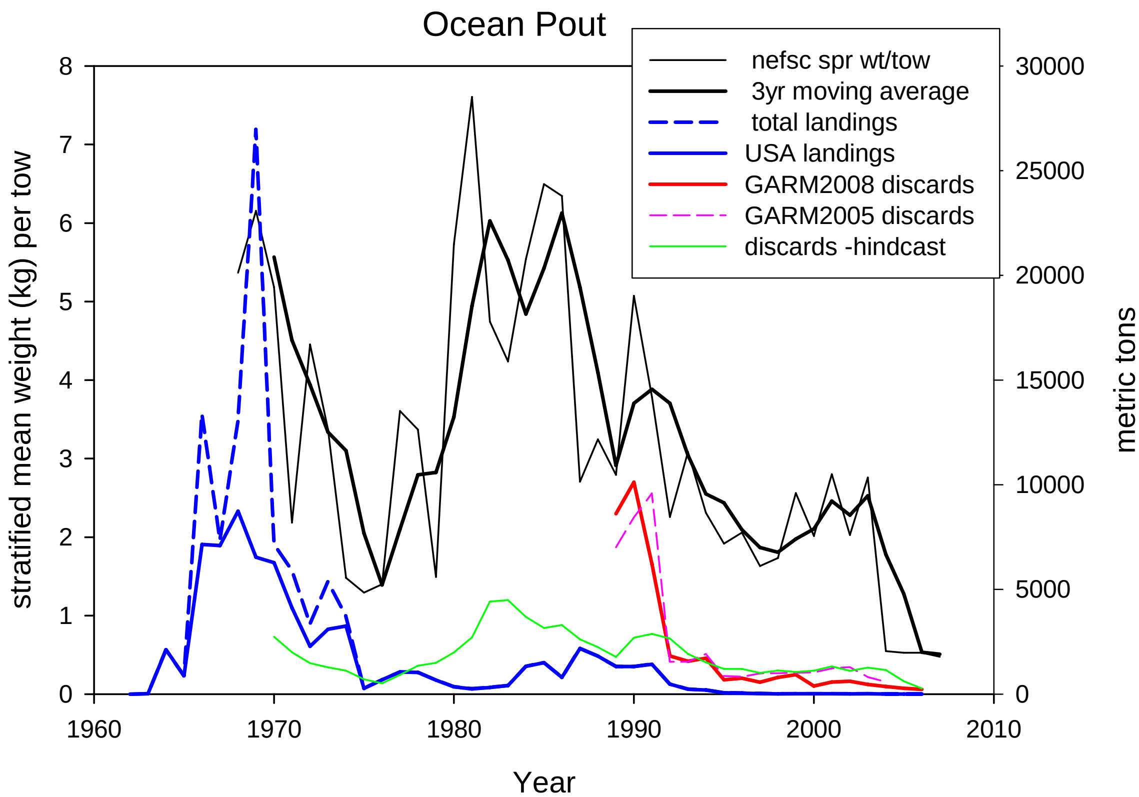

Figure 2. Comparison of ocean pout commercial discards estimated using the survey-scale method and discards estimated using the combined-ratio method (GARM 2008), as well as discards estimated using a discard to days absent ratio (GARM 2005).